Cellulose: New products from an old molecule

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Cellulose is the most abundant biomolecule in the world. Today the bulk of cellulose is used as either wood or pulp where the native cellular structure of the organism is preserved. Smaller amounts are fully dissolved and formed into fibers or films devoid of all memory of the original structure. A middle ground that offers many new applications and opportunities is to eliminate the cellular structure but preserve the microfibrillar structure or, possibly, chop these microfibrils into shorter segments - cellulose nanocrystals. Since the microfibrillar lateral dimensions are less than 5nm for wood or cotton and even the largest microfibrils, those from *Valonia* spp. or tunicates, have lateral dimensions below 30nm. Particles and filaments in this regime are likely to differ significantly in terms of their physical properties. From their micro scale and larger counterparts. In additional the increased specific surface area characteristic of decreasing particle size also suggests changes in the chemical properties of the particles as a consequence of increased accessibility. We will discuss some of the ways in which these changes can lead to new value-added materials and the current state of such products. Many, if not most, of these products can be produced from cellulosic waste streams such as sawdust, straw, fruit pulps left after juicing, bagasse, sugar beet residues etc. or from recycled cellulose containing

Nanoparticulate Fillers

Nanocrystals of cellulose are made by disrupting bleached plant cells into individual microfibrils and then hydrolyzing the non-crystalline regions leading to the production of needle-like crystals a few nm across and up to a ?m in length. The crystals are then dispersed in a polymer matrix and extruded or cast into film, fiber, object etc. We have explored a range of surface derivatizations including trimethylsilyl groups, organic esters including maleic acid in an attempt to control surface hydrophilicity/ hydrophobicity and thus enhance compatibility between nanocrystal and matrix. In a more recent venture, we are exploring the grafting of oligomeric and polymeric side chains to the cellulose surface. Results of both the synthetic procedures and the thermo/mechanical/rheological properties will be summarized.

Chiral Separation Media

Chiral separation media are becoming increasingly important in the pharmaceutical industry because of requirements to either produce chirally pure drugs or to independently characterize and validate each of the constituent isomers found in a new drug before a license is granted. Production of optically pure drugs sometimes can be accomplished by chiral synthesis as in the case of S-ibuprofen. However, resolution of the synthetic product into its separate optical isomers on a commercial scale is also an attractive approach. Daicel, for example, has been using silica particles coated with cellulose derivatives such as carbamates as separation media for chromatography and fluidized bed operations for several years. Our approach is to use the same cellulose crystals described above and then carbamate the surfaces. This is very preliminary work at present although we anticipate presenting preliminary data on the enantioselectivity of such compounds.

Stimuli Responsive Materials

A stimuli responsive material is a material that undergoes an, ideally, reversible change in one or more physical properties in response to the application / removal of some external stimulus. For electrorheological materials a viscosity change is induced by the application of an external electric field. For magnetorheologic materials a magnetic field change causes a corresponding change in the system viscosity. pH, ionic strength, temperature are other examples of physical properties whose value might effect the physical properties of a material. The low cost of cellulose coupled to its thermomechanical stability and resistance to abrasiveness makes such molecules good candidates for the particulate phase of such materials. The ease of derivitization for cellulose makes a variety of surface chemistries possible. Work to date is leading us towards the introduction of quaternary amine functionality on the surface, mimicking a chitosan type structure but having the poorer solubility of cellulose.

Conclusions

We believe there are many opportunities for the development of novel products and materials from cellulose. For such products to compete effectively with petroleum based products, we are focused on those areas where uniqueness of the product offsets any economic advantage of using petroleum based products. In our particular cases, we are seeking to utilize the nanoparticulate nature and stability of our crystals to provide this advantage.